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Eco-friendly Machining of T6061 Aluminium Alloy using Titanium Carbonitride (TiCN) Coated Tools

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Abstract. Traditional wet machining methods using oil based cutting fluids and water based cutting fluids are currently being used widely in the industry. Since oil based cutting fluids contributes to environmental problems, water based cutting fluids were introduced to minimize these effects even though not extensively used everywhere in all parts of the world. Eco-friendly machining is introduced for making the environment a better and healthier place by reducing the amount of contaminants and pollution into the water system. Two biodegradable cutting fluids have been chosen in this study; vegetable oil (palm oil) and water based cutting fluids. The wear behavior of TiCN coated tools is studied for three different cutting speeds (333, 415 and 517 m/min) and at two different cutting parameters; depth-of-cut, d and feed rate, f (d = 0.2 mm, f = 0.4 mm/rev and d = 0.4 mm, f = 0.6 mm/rev). Wear rate for machining using palm oil cutting fluid is lower (longer tool life) than the wear rate obtained from using water based coolants. Palm oil has better lubrication properties compared to water based coolants which have better cooling effects. The optimum cutting parameters for machining T6061 Aluminium alloy using TiCN coated tool is found; 333 m/min (water based) and 415 m/min (palm oil) at a depth of cut of 0.4 mm and feed rate of 0.6 mm/rev.

Introduction

Traditional wet machining methods lead to several environmental problems such as global warming, discharge of the emission and increased consumption of energy with the use of chemical substance. Some eco-friendly machining methods, such as minimum quantity lubricant (MQL) machining and cold-air jet machining methods have been recently developed instead of the traditional wetting machining [1,2]. Unist Australia applies neat 100% Coolube 2210 vegetable oil to the cutting area in order to reduce the friction, therefore reduce the heat as opposed to the old way of creating heat then cool it down with coolant which is 98% water and a bit of oil [3]. This way, flood coolant can be eliminated. MQL systems help ensure that cutting oil always gets to the right place. This concept delivers an oil/air mixture to the cutting point through passages in the spindle, toolholder, and cutting tool.

The use of cutting fluids help increase the tool life and improve the efficiency of the production systems providing both cooling and lubricating the work surface. T6061 Aluminum alloy has a wide range of mechanical and corrosion resistance properties as well as having most of the good qualities of aluminum. It is used in many applications from aircraft structures, yacht construction, truck bodies, bicycle frames to screw machine parts. Many researchers have done experiments to machine hardened steel under various types of machining processes by using different types of tools [4-8]. Limited studies have been conducted on machining of T6061 Aluminum alloy using palm oil cutting fluid [9-10]. No studies have been performed particularly on TiCN coated tools using palm oil as the cutting fluid. This paper aims to obtain the optimum cutting parameters for machining T6061 Aluminum alloy using TiCN coated tools by eco-friendly means (using palm oil and water based cutting fluids).

Experimental Method

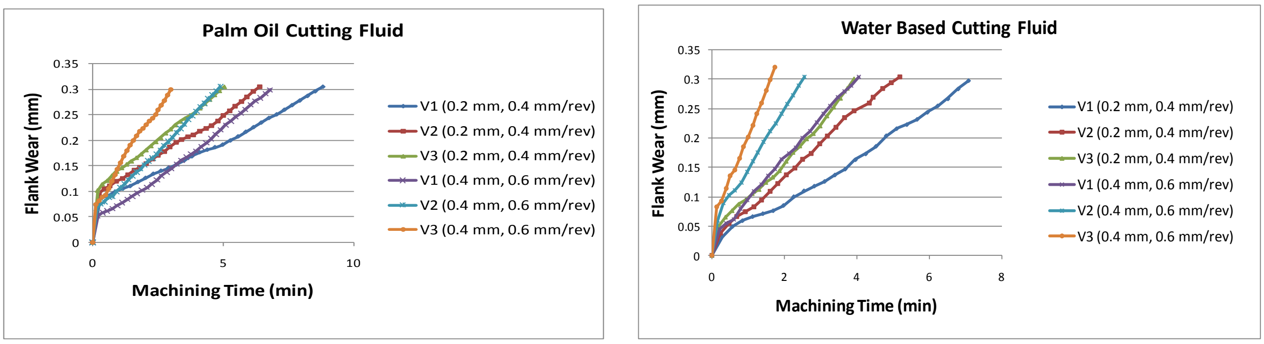
Work Material Preparation. The aluminum alloy rod was fixed into the 3 jaw chuck of the lathe machine (HARRISON M600). The raw T6061 Aluminum alloy rod with a diameter 136 mm was straight turned several times to perform the skinning operation. Then the work material was measured to 80 mm apart and marked with a groove into 5 equal sections.

Machining. The Titanium Carbo Nitride (TiCN) coated triangular tool insert (SANDVIK COROMANT) was inserted into the tool holder (MTJNR 2525 M16K) at the tool post and was secured. The initial diameter of the aluminum alloy rod was measured every time prior to machining. Machining was performed at three different cutting speeds (333, 415 and 517 m/min) at two different cutting parameters; (d = 0.2 mm, f = 0.4 mm/rev and d = 0.4 mm, f = 0.6 mm/rev). Time to machine each slot was recorded.

Temperature and Wear Measurement. During the machining process, tool tip temperature was measured using an Infrared thermometer (ST-677 HDS). After machining each segment, the tool was removed from the tool holder for wear measurement by using an Optical Microscope (Nikon MM-400).

Results and Discussion

Wear Analysis. The wear measurement results of TiCN coated tool using palm oil and water based cutting fluids are plotted by means of extrapolation (until maximum amount of 0.3 mm of flank wear) into graphs as shown in Fig. 1. Wear progression is more prominent from using water based coolant as a result of higher wear rates when compared to machining using palm oil. It is noticed that using palm oil has produced a larger initial tool wear compared to using water based coolant. However, it resulted in a lower wear rate eventually. This was observed for both cutting parameters (d = 0.2 mm, f = 0.4 mm/rev and d = 0.4 mm, f = 0.6 mm/rev).



(a) (b)

Fig. 1: Flank Wear Measurements of TiCN Coated Tool (a) Palm Oil (b) Water Based Cutting Fluid

Machining using palm oil apparently has shown to have lower wear rates (0.02, 0.03 and 0.05 mm/min) for TiCN tool when compared to machining using water based cutting fluid (0.03, 0.05 and 0.06 mm/min) at 333, 415 and 517 m/min respectively for d = 0.2 mm and f = 0.4 mm/rev. Similarly, when machining at d = 0.4 mm, f = 0.6 mm/rev, machining using palm oil has shown to have wear rates of 0.05, 0.07 and 0.11 mm/min which are relatively lower when compared to machining using water based cutting fluid (0.08, 0.12 and 0.17 mm/min). The wear rates (slopes) from Fig. 1 are found in order to obtain the tool wear intensities for the TiCN coated tool (Fig. 2).

Despite having higher initial wear, usage of palm oil has resulted in reduction of tool wear intensities by 19-38% and 37-50% when compared with the usage of water based cutting fluid when machined at both cutting parameters; d = 0.2 mm, f = 0.4 mm/rev and d = 0.4 mm, f = 0.6 mm/rev respectively. This is a clear indication that water based cutting fluids lack lubrication properties unlike in palm oil which resulted in a better tool performance. Tool life graph for TiCN coated tool was obtained (Fig. 3) for both machining conditions. The exponential values (n) were found from the slopes of the tool life curves based on the Taylor's tool life equation (Eq. 1),

$$V\,T^{\,n} = C \tag{1}$$

where V is the cutting speed, T is the tool life and C is the constant value. The *n* values for both cutting conditions were found to be around 0.45-0.5 which is in the range of carbide tools. Using palm oil has increased the tool life by 7.65 - 23.9% and 21.5 – 48.5% for *d* = 0.2 mm, *f* = 0.4 mm/rev and *d* = 0.4 mm, *f* = 0.6 mm/rev respectively when compared to using water based cutting fluids. Data on tool life can be seen in Table 1. However, when machining at *d* = 0.4 mm, *f* = 0.6 mm/rev, tool life from using palm oil has reduced by 33 -36 % compared to when machined at *d* = 0.2 mm, *f* = 0.4 mm/rev. This is in accordance with the known fact that higher cutting parameters will result in a lower tool life. Material removal rates were calculated using Eq. 2,

$$MRR = \pi\, D_{avg}\, d\, f\, N \tag{2}$$

where D_{avg} is the average diameter, *d* is the depth-of-cut, *f* is the feed and *N* is the spindle speed used in rpm. Obviously, the larger cutting parameters (*d* = 0.4 mm, *f* = 0.6 mm/rev) resulted in larger values of MRR (about 200% increment) as shown in Fig.4. Basing on the relationship of tool life and MRR values, the optimum cutting parameters can be found. Tool life of TiCN tool decreased by 36% and 45%, when the cutting speed was increased from 333 to 517 m/min for palm oil and water based cutting fluids respectively. However, MRR increased by 55% for both cutting parameters. Larger amounts of volume removal are found from using palm oil compared to using water based coolant. Thus, palm oil seems more suitable for machining at a higher speed (415 m/min) compared to water based coolant (333 m/min) at *d* = 0.4 mm and *f* = 0.6 mm/rev.

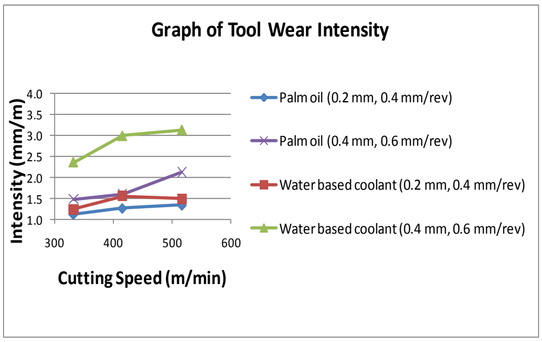


Fig. 2: Tool Wear Intensity (TiCN Coated Tools)

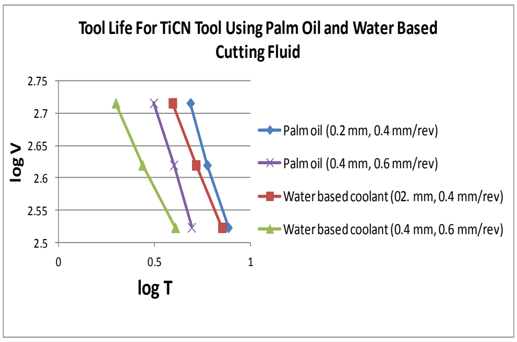


Fig. 3: Tool Life Curves (TiCN Coated Tools)

Table 1: Tool Life and MRR Values for TiCN Tools from Using Eco-friendly Cutting Fluids

Cutting Speed (m/min)	Cutting conditions	MRR (mm^3/ min)	Tool life (min) (water based)	Tool life (min) (palm oil)	Increase in Tool Life (%)
V1 (333)	0.2 mm, 0.4 mm/rev	26604	7.09	7.63	7.65
V2 (415)		33154	5.18	5.93	14.50
V3 (517)		41317	3.91	4.85	23.89
V1 (333)	0.4 mm, 0.6 mm/rev	79872	4.04	4.91	21.54
V2 (415)		99237	2.73	3.98	45.87
V3 (517)		123386	2.10	3.12	48.50

Temperature Analysis. Tool tip temperature was analyzed for TiCN coated tool during machining using both palm oil and water based cutting fluids. Results from both cutting parameters and cutting conditions are shown in Fig. 5. Results clearly indicate that machining of T6061 Aluminum alloy using palm oil cutting fluid has shown an increase in the average tool tip temperature by 5-8% and 4-10% for *d* = 0.2 mm, *f* = 0.4 mm/rev and *d* = 0.4 mm, *f* = 0.6 mm/rev respectively when compared to machining using water based cutting fluid. This shows that water based cutting fluid has better cooling effect properties even though it lacks lubrication properties which resulted in a larger wear rate.

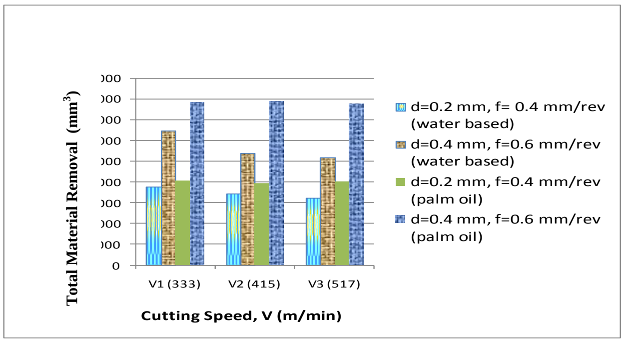


Fig. 4: Total Material Removal for TiCN Coated Tools

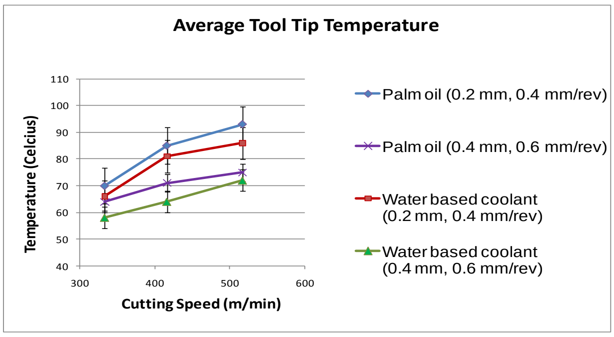


Fig. 5: Graph of Average Tool Tip Temperature

Conclusions

Machining using palm oil cutting fluid resulted in lower tool wear rates, lower tool wear intensities and longer tool life when compared to using water based cutting fluid at high speed machining. Palm oil has better lubrication properties than water based cutting fluid which aids in reducing friction during the turning process. The increase in the average tool tip temperature from using palm oil cutting fluid is too small (5-10%) when compared to using water based cutting fluid at high speed cutting. The small temperature rise in this case is insignificant in influencing the wear rate. This indicates water based coolant has better cooling properties in order to reduce temperature during machining process. Considering the properties of TiCN coated tool which is suitable for high speed machining and interrupted cutting environment, the optimum cutting conditions for machining T6061 Aluminium alloy is found to be using palm oil cutting fluid with the cutting speed of 415 m/min, depth-of-cut of 0.4 mm and feed rate of 0.6 mm/rev.

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References

[1] T. Shojiro, O. Shigetoshi, K. Kunio and T. Masayosh, Int. J. Jpn Soc. Precis. Eng. 69 (2003) 825-830.

[2] M. Tolinski, Near-Dry Machining Cuts the Heat, Manuf. Eng.138 (2007) 19-23.Information on http://www.industrysearch.com.au/Suppliers/Unist-Australia

[3] S.Y. Luo, Y.S. Liao, Y.Y. Tsai, Wear characteristics in turning high hardness alloy steel by ceramic and CBN tools, J. Mater. Process. Technol. 88 (1999) 114–121.

[4] J. Barry and G.Byrne, Cutting tool wear in the machining of hardened steels Part I: alumina/TiC cutting tool wear, Wear. 247 (2001) 139–151.

[5] A. Senthil Kumar, A. Raja Durai, T. Sornakumar, Machinability of hardened steel using alumina based ceramic cutting tools, Int. J. Refract. Met. Hard Mater. 21(2003) 109–117.

[6] H. Geng, X. Wu, H. Wang, Y. Min, Effects of copper content on the machinability and corrosion resistance of martensitic stainless steel, J. Mater. Sci. 43 (2008) 83–87.S.

[7] Sharif, M.A. Hisyam, S. Aman, Evaluation of vegetable oil as an alternative cuttinglubricant when end milling martensutic stainless steel using uncoated carbide tool, Int.J. Adv. Manuf. Technol. 3 (2009) 49-55.

[8] J. B. Mann, C. Saldana, W. Moscoso, W. D. Compton and S. Chandrasekar, Effects of controlled modulation on interface tribology and deformation in machining, Tribol. Lett. 35 (2009) 221-227.

[9] J. Destefani, Ultrasonic atomization of fluids improves micromachining, Micromanufacturing. 4 (2011).